Application of Blockchain in Three-dimensional Land Management

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Abstract. At present, with the rapid development of urbanization in China, the concept of urban intensive development has been widely concerned. With the increasing number of excellent cases of three-dimensional land development (such as Shenzhen Qianhai), three-dimensional land management is facing double challenges in time and space. It is urgent to optimize the management mechanism and build a credible and efficient system to meet the collaborative needs of multi-agents participating in three-dimensional land development. First of all, it studies the inevitability of the development of urban construction land from two-dimensional development to three-dimensional development, and introduces blockchain technology to solve the problems of data security storage, transparency and credibility, tamper-proof traceability, privacy security and high reliability of the system. Then, the overall architecture system based on alliance chain is designed, and a system for managing the full-cycle development of three-dimensional composite multifunctional complex is built. The results show that the three-dimensional land management system based on Hyperledger Fabric can effectively promote the management of the whole life cycle of three-dimensional land development by various management departments, and coordinate the conflicts in time and space when the construction subjects develop the same three-dimensional composite urban complex.

Keywords: Blockchain; Hyperledger Fabric; Three-dimensional land management; Spatio-temporal coordination

1 Introduction

Under the background of the development and construction of megacities and urban agglomerations, the contradiction between the continuous population accumulation and high-frequency human activities and the limited supply of land resources has become increasingly prominent. As an effective way to intensively develop the city and give full play to the urban spatial efficiency, the multi-functional and three-dimensional urban complex is booming in China, and its functional connotation and spatial organization have improved qualitatively and leaped quantitatively compared with the previous single-function surface space. With the large-scale utilization of high-rise buildings, three-dimensional traffic, underground rail transit, underground shopping malls and other above-ground and underground spaces, the compound three-dimensional development of land covers a complex land management form from two-dimensional to three-dimensional, single-functional to compound, and the development subject from unilateral independence to multi-party cooperation. How to make all parties reach a consensus in every link of the development process, especially the "spatial coordination

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consensus", and on this basis, efficiently and cooperatively complete the three-dimensional development of land, which is the primary problem to be solved urgently in the land management of the central city and economic development-intensive areas of big cities[1].

In recent years, blockchain, as a new decentralized and distributed storage technology, has developed rapidly in many fields. Because of its technical characteristics, such as transparency and credibility, tamper-proof traceability, privacy security and high reliability of the system, it is suitable for multi-state, multi-link and multi-party collaborative application scenarios and has natural advantages in solving the above land management problems. This topic intends to take the space-time coordination of land management as the research object, and from the technical point of view, analyze how to reach a spatial consensus among multi-parties in the process of land compound three-dimensional development; On this basis, the theoretical model and technical framework of spatial-temporal collaboration of three-dimensional land management based on alliance chain technology are developed, and the key technologies and methods are prototyped to verify their rationality and feasibility.

In the research of three-dimensional land management based on blockchain, many scholars have made rich achievements, such as being widely used in land registration, cadastral boundary violation detection, real estate transaction, BIM and other fields[2]. In land registration, because land transaction records are one of the most important records produced by society, it is of great significance to individuals and society, so it is necessary to properly handle and maintain land transaction records, and using blockchain technology to conduct land transactions can improve processing efficiency, reduce the processing cost of land transactions, and. Prevent the owner from cheating; Increase security, auditability and transparency; And enhance people's confidence in land management[3]. At present, the use of blockchain technology for land transaction registration has been piloted in Brazil, Sweden, Ukraine, India and other places[4] and achieved certain success. In the aspect of cadastral boundary violation detection, the management of cadastre has become relatively difficult due to the complexity of geographical space, so there may be inconsistent cadastral boundary measurement in the process of cadastral coordination and collaborative management. In view of this situation, Torun, a foreign scholar, proposed a CAD/GIS method based on blockchain technology to prevent such things from happening. In this method, unless or with the joint approval of all stakeholders, the land registry will not register transactions that change the boundary. In the aspect of real estate registration, because there are many departments involved in real estate registration, such as planning, land approval, construction, transaction, taxation, household registration, etc., blockchain technology can provide reliable technical support for promoting the networked and intelligent development of real estate registration with its distributed storage, reliable data, and traceability throughout the process[5].

2 Research on Spatial-Temporal Synergy of Land Stereo

2.1 Three-dimensional land use

With the deepening of urbanization in China, the contradiction between the continuous population accumulation and the limited supply of land resources has become increasingly prominent. As an effective way to intensively develop the city and give full play to the urban spatial efficiency, the multi-functional and three-dimensional urban complex is booming in

China, and its functional connotation and spatial organization have improved qualitatively and leaped quantitatively compared with the previous single-function surface space. High-rise buildings, three-dimensional traffic, underground rail transit, underground shopping malls and other above-ground and underground spaces are used on a large scale. The compound three-dimensional development of land covers a complex land management form from two-dimensional to three-dimensional, single-dimensional to compound in function, and the development subject from unilateral independence to multi-party cooperation.

2.2 Spatio-temporal coordination

The management nodes in the linear process of land management are isolated from each other, and it is easy to form information islands. The subjects of management business within the nodes are diversified, and the collaboration between different subjects lacks information means, which is easy to cause problems such as low communication efficiency, high decision-making cost and unbalanced collaboration. This paper intends to analyze the transition state of land spatial form in different management nodes and the collaborative mechanism of multi-subject spatial consensus from the vertical and horizontal dimensions of management process, so as to provide basic (theoretical) support for building a spatio-temporal blockchain integrating spatial information. The specific research contents are as follows:

(1) horizontally analyze the expression characteristics of spatial elements corresponding to different subjects, such as planning, cadastre, fire protection, civil air defense, etc., whether it is a two-dimensional graphic or a three-dimensional space, and the expression of specific elements of space, such as withdrawing fire protection space and civil air defense space from the design space; The mutual restraint relations, norms and rules of spatial collaborative consensus among different subjects, and the corresponding spatial information model expression strategies, such as management subject and management subject, development subject and design subject, management subject and development subject, management subject and design subject, development subject and development subject, design subject and design subject, etc.

(2) vertically analyze how the information and management attributes of spatial elements flow between management nodes with sequential correspondence in linear flow, and the relationship between constraints and feedback, especially the compatibility of spatial information in different dimensions, such as the information transmission, constraints and feedback mechanism between two-dimensional space in the upstream link and three-dimensional space in the downstream.

2.3 Application of alliance chain in three-dimensional land management

In the traditional whole-cycle land use process, the centralized land development process system is generally controlled by the administrative organs of various departments involved in the project, and the data security and sharing cannot be guaranteed. Because the engineering data in the project has certain innovation and high value, such "data assets" are kept in a centralized system that is opaque and not open to the original owner of the data, which is equivalent to losing the control right of the engineering data on their own initiative. The data owner not only faces the risk of infringement of rights and interests, but also may lose important data due to a single point failure of the centralized system, which is at a disadvantage when commercial disputes or problems are pursued. The lack of trust between the parties involved in the three-dimensional development and cooperation of land has a profound historical influence. The separation of processes caused by the formation of data islands among various business systems is partly caused by the complexity of the project itself. Three-dimensional land management based on alliance chain technology involves organizations including management subject, construction subject and all owners. Among them, the main management organization includes sub-nodes such as natural resources department, development and reform commission, municipal department, housing and construction department and ecological environment department; The main organization of construction includes five sub-nodes: construction unit, survey unit, construction unit, supervision unit and design unit. All owners include property owners at all stages in the whole cycle of land use. Using channel technology, the relevant parties in each stage of land development are connected to a network with distributed account books, and the required data, contracts and other important data are stored on the chain. Realize the management and inquiry of land ownership, the publicity of land planning, the supervision of land construction and reduce contract disputes. The blockchain runs through the whole cycle of land circulation, and the chain keeps the certificate and tracks the change of land ownership. At the same time, it uses the time stamp feature to record, prove and pursue the responsibility of each link.

2.4 Hyperledger Fabric-based three-dimensional land management challenges

In view of the above problems, this section discusses in detail the challenges faced by the three-dimensional land management system based on alliance chain: 1. Ensure the safety of engineering data. The characteristics of engineering data are recorded in the distributed ledger of alliance chain technology, which realizes the tamper-proof, traceability and safe storage of engineering data. 2. Guarantee the data sovereignty of all parties involved in the construction of the project data. The contractor can control the engineering data ontology from beginning to end. 3. Standardize the subcontracting mechanism and contract management. In the process of project cooperation, the subcontract relationship and terms between the general contractor and all the participating parties should be transparent and open within the project, which can be checked by both parties at any time. It is not allowed to sign the subcontract illegally or change the contract terms privately. 4. The project schedule is credible and controllable. The progress of each sub-item of the project is summarized to form the project footprint, and the project team members should be able to accurately grasp the overall progress of the project at any time through the project footprint. At the same time, the construction progress of each sub-item must be documented, and after the project construction has problems, they can accurately pursue the responsibility through the historical progress data in the distributed account book. 5. Organization internal authority management. Control the operation authority of system resources by members of different ranks and departments in the organization to avoid unauthorized operation or cross-organization management. 6. Reliable sharing of engineering data. Engineering data should be credible and accessible among project team members, and the leakage and tampering of engineering data in the whole life cycle of the project should be avoided as much as possible in the data circulation process, so the data circulation process needs to be traceable, and the data requester can verify the data integrity through technical means after receiving the data. 7. Minimize the workload of business system transformation. The business system access system and alliance chain network of the contractor need to be reformed to some extent. By providing RESTful API, the workload of transformation and the code intrusion into the business code in the business system of the contractor can be reduced. 8. Adopt hierarchical architecture. By layering, the complexity of the system is reduced, the implementation details of the bottom layer are shielded from the upper layer, the difficulty of system maintenance and subsequent development is reduced, and new application systems can be developed by reusing the bottom infrastructure.

3 Design of three-dimensional land use system based on Hyperledger Fabric

3.1 Demand analysis

As the infrastructure of the three-dimensional land use system, Hyperledger Fabric needs to select an appropriate consensus mechanism according to the needs of the blockchain in land management and the characteristics of the emergence and disappearance of land in the whole life cycle, which not only reflects the process of alliance members participating in reaching consensus, but also reduces the requirements for the digitalization level of organization members participating in the consensus formation process while taking into account the efficiency and safety of consensus. In order to reflect the participation of multiple organizations and reach a consensus, the alliance chain network needs to include Orderer nodes and peer nodes of multiple organizations. In addition, there must be a CA service for managing member certificates and keys, because new users will join in the process of system operation. As the embodiment of system business logic in alliance chain network, smart contract needs to be closely integrated with the original process of the participants in the whole life cycle of the construction project. On this basis, developers need to give full play to the advantages of smart contracts in terms of cost efficiency, digitize and automate processes, and at the same time, summarize a set of standardized processes and contract templates, so as to facilitate enterprises with different digital levels to develop smart contracts and deploy them into the channels to which the projects belong. As a barrier to isolate data between different projects, the situation of the channel is closely related to the situation of the project. In the process of project collaboration, when the project is created and the project team changes, it needs to be reflected in the corresponding channel. In this way, a lot of work has to be done to create channels, update configurations and add or delete organizations. In order to reduce the pressure of operation and maintenance, the system needs to automate and simplify these tasks and help the operation and maintenance personnel to complete the above work easily.

3.2 Overall system architecture

Blockchain is essentially a distributed database with a specific structure. The general standard blockchain project includes at least three parts: data layer, network layer and consensus layer, and can also include three parts: incentive layer, contract layer and application layer. Data layer, network layer and consensus layer are the core contents of Hyperledger Fabric framework, which mainly include identity verification, block production and synchronization, consensus mechanism management, transaction verification and smart contract management. Fabric framework itself integrates the functions of these three layers. Among them, the status database in Hyperledger Fabric mainly stores transaction block data, land asset data and authentication data, while MySQL database mainly stores user registration data and other land transfer related data. The contract layer mainly includes all kinds of script codes, algorithm mechanisms and smart contracts. The contract layer under the fabric framework mainly develops and manages chain codes. Smart contracts are called chain codes in Hyperledger Fabric. They can be deployed in the network nodes of Hyperledger Fabric or run independently in the protected Docker container with security features, and communicate with the responding Peer nodes with gRPC protocol. The contract layer is divided into two parts: business contract and system contract. The business contract mainly includes the registration of land transfer transactions, the authorization of land transfer transactions, the renewal of land management rights, land filing, etc. The system contract mainly includes the inquiry of transaction block information provided by Fabric framework, the signature of Endorsc node and the transaction verification of Commit node. The application layer is the view interface layer of the system, which adopts B/S architecture and is divided into browser and server. It is designed by MVC design pattern. The browser mainly uses HTML, CSS, JavaScript and other languages to design the user interface, while the server uses Golang language to design, because Golang language itself provides a Web server to process HTTP requests and provides templates for HTML pages. The application layer designs the interface layer through fabric-sdk-go provided by Hyperledger Fabric to realize data interaction between the application layer and the contract layer. The specific system architecture is shown in Figure 1.

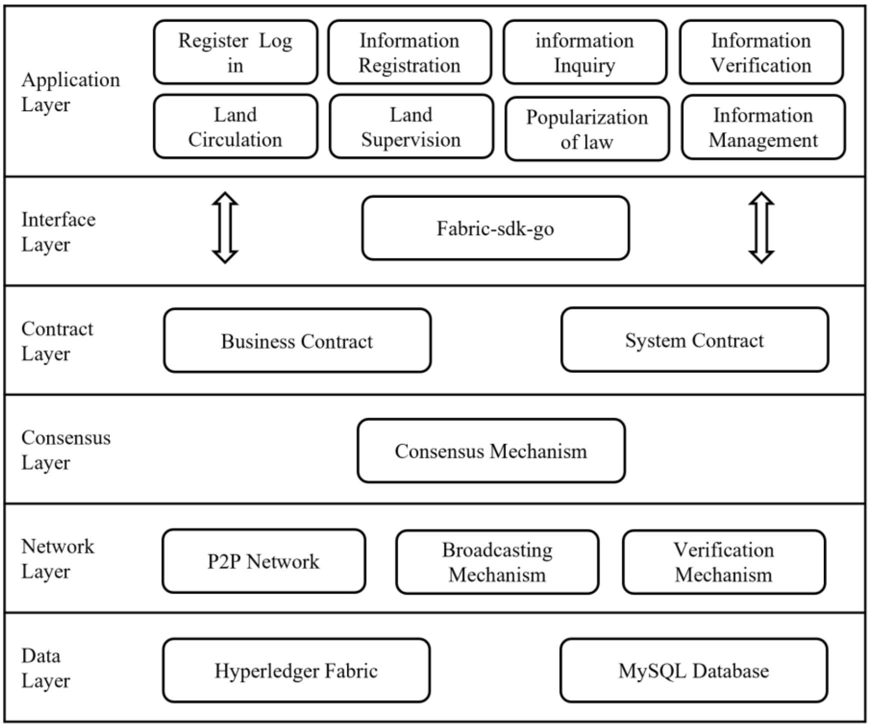

Fig.1 Overall system architecture diagram

3.3 System functional structure design

In order to simplify the difficulty of system implementation, the author decouples all the complex functions in the system according to their functions and modularizes them, and divides the whole system into four main components: blockchain platform, user management module, project management module and data management module, and several subordinate sub-functional modules. The overall functional structure design of the system is shown in Figure 2: Among them, the blockchain platform is mainly responsible for building the blockchain network and ensuring that the blockchain network can meet the cooperation needs of construction projects in the system; The user management module is mainly responsible for the management of users, including the organization joining the alliance, the application and use of multiple accounts within the organization and the corresponding internal authority control; The project management module is mainly responsible for the management of construction projects, which is the most helpful part for the project collaboration function of the whole system. The module includes the functions of project creation and approval, project team establishment and management, project application review and progress summary, and the setting of project corresponding attributes. The data management module is mainly responsible for the release, storage, sharing and inspection of engineering data, and ensures the digital sovereignty of all contractors and the credibility, reliability and accessibility of engineering data within the project during the project life cycle.

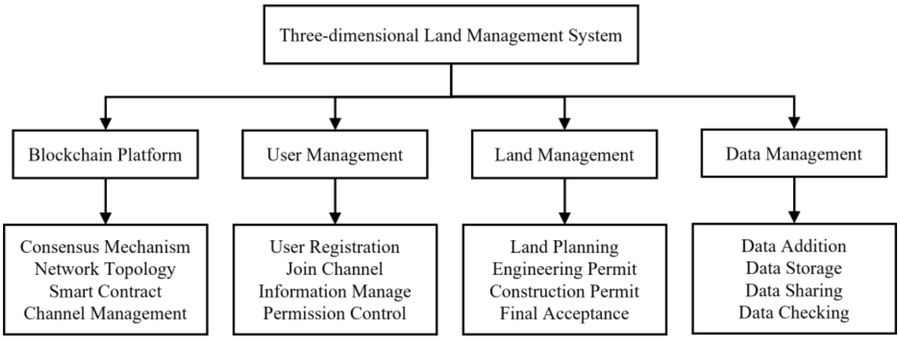

Fig.2 Overall functional structure diagram of the system

4 Performance testing and analysis

4.1 System development environment

In the whole project development process, the author's development environment is mainly built on a host computer using Windows10 64-bit operating system (the machine is configured with Intel core i5-8400 processor, 16GB memory and 1T solid state drive), and the IDE used in the development process is IntelliJ IDEA 2019.2.1. Fabric blockchain network nodes and Fabric CA services are deployed on multiple Linux servers using CentOS 7 operating system (the servers are configured with 4 cores and 4GB of memory). The back-end framework of the system adopts SpringBoot, and the front-end framework adopts Vue.js. The underlying alliance chain support adopts Hyperledger Fabric framework which is open source by IBM. The version of Fabric framework is 2.0, the version of Docker CE container used for deploying alliance chain nodes and Fabric CA nodes is 20.10.0, and the version of Docker-Compose tool is 1.25.4. The relational database management system MySQL version used in the back-end is 5.7.24, the software development kit version used in the back-end Java development is jdk-8u201-windows-x64, the project management tool Maven version used in the back-end development is 3.3.1, and the version control tool in the project development process is Git.

4.2 System implementation

The host operating system used in this system is Cent OS 7, and the Hyperledger Fabric version is 2.0.0,Fabric network nodes are deployed in different server Docker container images. There are three organizations in the whole alliance chain network, and each organization has one orderer node and two peer nodes. In the system design, the channel is used as a means of information isolation between different projects. Therefore, using the command line to manually generate channels will bring too much workload to users and maintenance personnel, so the system uses the template engine to automatically generate the configuration file of the corresponding channel according to the project settings, and then generates the corresponding configtx.yaml configuration file through the configuration file, and finally calls the shell script to automatically create the channel using the configtxgen tool. In Hyperledger Fabric, smart contracts are often called chain codes, but in fact, smart contracts are an advanced abstraction, and chain codes are general containers that carry smart contracts and are deployed in Fabric networks. At present, Hyperledger Fabric supports the use of most mainstream programming languages for smart contract development. In this paper, in view of Java's rich language ecology and its power in building industrial projects, we choose to use Java language to develop smart contracts.

4.3 Performance test

The related indicators of system performance test mainly include: the time from the node submitting the transaction to the system leaving the block, the longest waiting time of the block, and the maximum number of transactions in the block, MCount. Among them, Btimeout and MCount are the system's blocking conditions, and one of them can be blocked.

Aiming at the concurrent transactions of multi-user nodes at the same time, the test of system block-out time is carried out to verify whether the system can meet the daily application requirements when dealing with multi-node concurrent transactions. The test setup is as follows: the user nodes in each organization continuously send 1000 BIM drawings to modify and submit transactions, and evaluate whether the average block-out time of the system meets the requirements, that is, it is less than the set maximum block-out time. In this study, according to the conventional setting of the Fabric alliance chain, the block out timeout (Btimeout) is set to 2 seconds, and the system includes 3 user nodes, so the maximum transaction count (MCount) is set to 3. A total of 20 tests were carried out, and the average block-out time was calculated after each test. The specific results are shown in Figure 3. The research results show that the block-out time shows an upward trend at first, until it reaches the maximum block-out time around the ninth test, and then the block-out time fluctuates up and down on the average. This phenomenon is because with the increase of test times, a large number of test data occupy the system memory, which has a certain impact on the system performance. After 20 tests, the average time for processing BIM drawing modification and submission transactions is 0.46785 seconds, and the maximum time is 0.55 seconds, which is far lower than the set maximum time of 2 seconds. Therefore, the experimental conditions meet the requirements of the maximum number of transactions in the block. The experimental results show that the system can effectively handle 3000 transaction requests submitted by three nodes simultaneously, which meets the application requirements of the normal system.

In view of the situation that many users have a large number of concurrent transaction requests, the processing speed of the system is tested to verify the processing speed of the system when dealing with multi-node concurrent transactions, under the condition of ensuring the stable block output within the maximum block output time. The test setup is as follows: the nodes in each organization send 400, 800, 1200, 1600, 2000, and 2400 transaction requests at the same time, and evaluate the processing rate of the system under the condition of keeping the maximum block ejection time stable. The test results are shown in Figure 4. According to Figure 4, with the increase of user request frequency, the system processing rate increases linearly at first, until the number of transactions per second reaches 1600, and the system processing rate is gradually saturated, which is about 1568 transactions per second. Subsequently, the system processing speed began to decline due to reasons such as memory occupation caused by excessive data. The experimental results show that the maximum processing rate of the system is 1568 transactions per second, which can fully meet the daily normal use needs of users and the standard of the system.

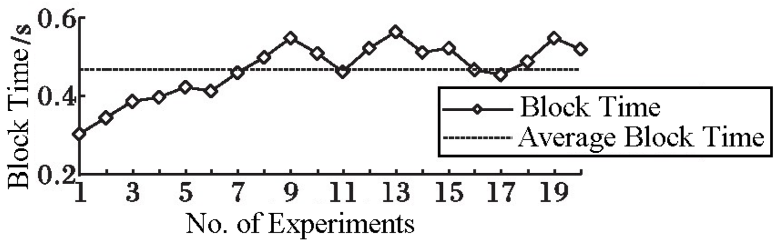

Fig.3 Block generation time

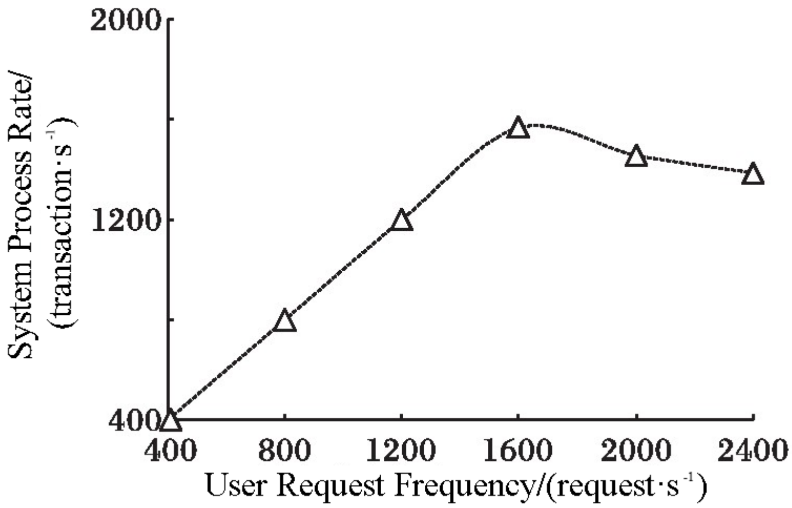

Fig.4 System processing rate

5 Conclusions

Aiming at the problem of three-dimensional land management, this paper applies blockchain technology to the field of three-dimensional land life cycle management, and explores the three-dimensional land management method based on Hyperledger Fabric. Firstly, the challenges faced by urban intensive development and three-dimensional land use are analyzed, and then the framework of Hyperledger Fabric for three-dimensional land management is put forward, which provides a new idea for realizing the safe sharing of data and the spatio-temporal cooperation in management among all links in the process of three-dimensional land management (such as planning, design, approval, supervision, construction, registration and acceptance) and various subjects of relevant parties (such as management subjects, design subjects, construction subjects, etc.). This research makes up for the block. However, the limitations of this study are also obvious, and the proposed framework needs more examples to support it. The research on blockchain technology in three-dimensional land use management is still in the exploratory stage, and this research may be a useful attempt. In the future, the research on three-dimensional land management in blockchain technology will also be discussed from multiple perspectives such as data security sharing, multi-agent collaboration, and policy formulation.

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